A Life Prediction Methodology for Delaminated Composite Structure: Mode-I Stress State

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ABSTRACT

Susceptibility to delamination is one of the major weaknesses of laminated composite structures. Knowledge of laminated composite material's resistance to interlaminar fracture and fatigue is essential to establish design allowables for damage tolerance analysis and design of structures. Based on TOGAA Committee's recommendation, the FAA's Rotorcraft Directorate chosen as a priority item to implement damage tolerance and fatigue evaluation for composite structures so that the rotorcrafts can be operated safely, inspected and repaired as needed. The approach proposed is similar to that of the metals technology. The laminated composite structures are assumed to have certain delaminations. Using fracture mechanics methodologies and a load spectrum, the number of flights or some other measure, the delamination growth life of the structural component can be determined. Based on this delamination growth life, suitable inspection intervals are established so that delaminations can be found and repaired long before they become critical or exceed the residual strength of the component. The effectiveness of damage tolerance analysis depends on many factors including fracture mechanics methodology, test methods and data, stress state, material database, environmental factor, etc. Delamination fracture toughness, onset life, toughness threshold, and growth rate are required for damage tolerance analysis and design of laminated composite structures. Although the problem of delamination in composites has been widely studied, the technology to predict the total life is very limited or non-existent. Even the models of propagation life and test methods are very limited. ASTM has test standards only for mode-I fracture toughness and initiation life and mixed-mode (I-II) toughness. Rotorcraft blades are subjected to torsional as well as in-plane loads; such problems require the materials mode-III toughness and grow rates for life prediction. Yet no accepted test specimen exists. In summary, extensive research needs to be done to develop life prediction methodologies for composite laminates. Although this paper does not address all the above problems, but attempts to address the life prediction methodology of laminated composites under mode I stress state.

Objective of this paper is to propose a fracture mechanics based delamination life prediction model under mode I stress state and present data for delamination onset life and growth rate for a rotorcraft material. The material chosen is Toray T800H/3900-2 unidirectional laminate. It is tested in mode-I loading according to ASTM D5228 and D6115 to measure the delamination toughness and onset life. Displacement controlled

constant amplitude mode-I fatigue testing is continued on the specimens to measure the growth rates. The data will be used to demonstrate the applicability of the model.